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TRADE-OFF FACTORS (NASA-CR-154822) AFFECTING THE METHOD OF CHARGING THE CM ATMOSPHERE FROM AIR TO OXYGEN IN FLIGHT 11 p LIMIT NASA (Bellcomm, Inc.)

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Trade-Off Factors Affecting the Method of Changing the CM

Atmosphere from Air to Oxygen

in Flight - Case 330

DATE: September 30, 1967

FROM: R. D. Raymond

# ABSTRACT

In the event that air is used as a CM cabin pressurant at launch a procedure will be required to change the cabin atmosphere to a higher oxygen composition in flight. The tradeoffs available for selecting a feasible procedure are discussed. The constraining parameters appear to be the percent of oxygen required, depressurization level, repressurization flow rates, time and oxygen system weight available.

Within the capabilities of the existing environmental system optional methods for changing cabin atmosphere include complete depressurization, partial depressurization and no depressurization. For each method certain constraining parameters are compromised more than others. Selection of the method that most enhances mission safety and operational capability requires determination of the relative criticality of the affected constraints. Only an indication of the sensitivity of various constraints to different procedures is discussed here.

One very reasonable method involving possibly acceptable trade-offs in constraining parameters is presented. The technique includes partial depressurization (to about 2 psia) followed by repressurization and purging. An 85% oxygen composition is achieved by T+95 minutes. Part of the gaseous oxygen supply is used (2.2 pounds) plus some from cryogenic storage (10 pounds). Unless one constraint becomes much more critical than the others. a procedure such as the above may become the optimum.

(NASA-CR-154822) TRADE-OFF FACTORS AFFECTING THE METHOD OF CHARGING THE CM ATMOSPHERE FROM AIR TO OXYGEN IN FLIGHT (Bellcomm, Inc.) 11 p

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SUBJECT: Trade-Off Factors Affecting the

Method of Changing the CM Atmosphere from Air to Oxygen

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## MEMORANDUM FOR FILE

# INTRODUCTION

If air is used as a CM cabin pressurant at launch, a change of cabin atmosphere will be required in flight to increase the oxygen content. The trade-offs required to make a selection of a procedure for changing from air to oxygen in the CM cabin are discussed. It is assumed that the existing system is used unchanged except that air is used as a cabin pressurant at launch.

The pertinent existing environmental control capabilities include the gaseous oxygen stored in the surge tank and three one-pound rapid repressurization bottles, the cabin repressurization valves and the cryogenic oxygen supply. It is assumed that the usable gaseous oxygen supply totals about 5.6 pounds, 2.2 pounds of which are available from the three one-pound bottles. The cryogenic oxygen supply is available at a rate up to 8.2 pounds per hour (limited by flow restrictors). The normal cabin repressurization valve used in a manual mode has a flow rate of about 0.12 pounds per minute (7.2 pounds per hour) and the emergency cabin repressurization valve has a flow rate of about 0.67 pounds per minute (40 pounds per hour) for one side. It is further assumed that the gaseous oxygen (at least the 2.2 pounds for rapid repressurization) can be used at the emergency repressurization rate and that the cryogenic supply can be used at the normal cabin repressurization rate.

The feasibility of providing the necessary functions is established based on oxygen availability (quantity and flow rates) and necessary controls. No attempt is made to predict the effect on existing tasks or time for necessary controls. The procedures discussed are started during the ascent phase to enable the earliest completion.

#### DISCUSSION

The parameters of cabin atmosphere changing techniques that most constrain the change procedure include:

1. Final percent of oxygen required in the cabin;

- 2. The minimum depressurization level;
- 3. The  $O_2$  flow rate for repressurization;
- 4. The time available for change over;
- 5. The weight allowance and oxygen available.

The cabin atmosphere change methods available with the existing system include:

- 1. Depressurization to zero and repressurization to 5 psia;
- 2. Partial depressurization to a level between zero and 6 psia and repressurization to 5 or 6 psia;
- 3. No depressurization, purge only at 6 psia.

The method of depressurizing to zero was evaluated by MSC and found to be feasible if certain adverse effects are acceptable. (1,2) The cabin pressure is reduced to nearly zero (<1 psia) and the cabin is repressurized to 5 psia using all available gaseous oxygen plus that additional required from the cryogenic supply. The dump and repressurization procedure duration is 30 minutes and the effect on the timeline is an addition of 20 minutes. The adverse effects include the effect on the timeline, the low cabin pressure (temporarily about zero), and the depletion of the gaseous oxygen supply. The major advantages include minimum oxygen required, relatively short time for the process and a high final oxygen content.

The criticality of a particular constraint may be the determinant in selecting a procedure. For example, if time is most critical and the procedure must be completed early, e.g., by a first translunar injection (TLI) opportunity of T+50 minutes, the only feasible method is to depressurize and repressurize rapidly using all available gaseous oxygen. By using oxygen purging data from a prior study on atmosphere enrichment it is possible to determine general sensitivities to varying the constraining values. (3) Also, some guidance on the time variations of importance is obtained from the design reference mission, e.g., if completion is required prior to TLI, one TLI opportunity of interest is T+95 minutes as used for the design reference mission. (4) The following examples indicate what can be accomplished with the existing spacecraft capabilities.

If some trade-off is available in the constraining parameters, a compromise procedure based on reasonable constraints is feasible. For instance, a partial depressurization method based on the following constraints is feasible. The constraints are negotiable, but the values listed appear to be about the minimum acceptable:

- 1. Change from air to 85% oxygen (at about 6 psia);
- 2. Depressurize to 2 psia;
- 3. Partial repressurization at rapid flow rate (0.67 lbs/min), maintain full surge tank for subsequent protection for cabin puncture, complete the repressurization at low flow rate (0.12 lbs/min);
- 4. Complete the process in time for a TLI at T+95 minutes;
- 5. Available oxygen includes about 2.2 lbs gaseous (from rapid repressurization system) and the cryogenic oxygen in the SM.

Within the above constraints the following procedure appears potentially feasible. The cabin depressurization cycle starts as early during ascent as practical after cabin pressure has stabilized at 6 psia; this would be about T+5 minutes. Depressurize to 3 psia and check suits; continue to 2 psia and stabilize to check cabin. Open the rapid repressurization bottles and dump contents of about 2.2 lbs of oxygen into the cabin, bringing the cabin pressure up to about 3.3 psia by T+8 minutes. Close the rapid repressurization valve and open the normal cabin repressurization valve. The cabin will continue to repressurize at a low flow rate, achieving full pressure of 6 psia (where the relief valve opens and purging starts) at about T+45 minutes (but only at 74% oxygen). Continue the purge until about T+95 minutes, at which time the cabin gas analyzer should indicate 85% oxygen in the cabin. The purge can then be discontinued. The pressure profiles for this procedure are shown in Figure 1 by the depressurize-to-2psia curves.

If further compromise of one or more constraints is acceptable, additional relief can be provided for another constraint. For example, if it is desired not to depressurize and more time is available, about 85% oxygen could be achieved by T+140 minutes (the next TLI opportunity) without using the gaseous oxygen supply. In addition, it is possible to achieve

about 74% oxygen by a TLI opportunity of T+95 minutes as shown in Figure 1 for the no-depressurization (6 psia) case.

Also shown in Figure 1 are repressurization curves for the complete depressurization case. Repressurization from 0 to 5 psia curves are shown with or without a period of rapid repressurization. It is seen that by depressurizing to zero and repressurizing from cryogenic supplies alone it is possible to achieve 100%  $0_{9}$  at a pressure of 5 psia by about 73 minutes. If the 2.2 pounds of gaseous oxygen in the rapid repressurization system is also used, 100% 0, at 5 psia is reached about 15 minutes earlier. This time can be further shortened by using a little more than the 2.2 pounds of gaseous oxygen.

Some of the relative trade-offs in terms of time, weight and oxygen content for three methods of cabin enrichment are shown in Table 1.

#### CONCLUSION

Cabin atmosphere enrichment can be accomplished using complete, partial, or no depressurization. The existing system is compatible with a wide choice of enrichment procedures. Determinant constraints appear to be time, pressure levels, percent oxygen and available oxygen.

If a high purity of oxygen is required (>95%) or if completion of the process must occur early (<T+1 hour) significant depressurization and use of some gaseous oxygen is necessary. However, if completion can be delayed (until about T+3 hours) or if only about 85% oxygen purity is required prior to TLI, the procedure does not necessarily require depressurization or use of the gaseous oxygen supply.

Selection of the most acceptable method of enriching the cabin atmosphere (with respect to optimizing mission safety and operational capability) requires determination of the relative criticality of the affected constraints. Unless one constraint becomes much more critical than the others, a compromise procedure involving partial depressurization and less than 100% oxygen may become the optimum solution.

Ph Raymond

R. D. Raymond

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Attachments Table 1 Figure 1

TABLE 1

# TRADE-OFF ENRICHMENT METHOUS

| OF OXYGEW RENAFIES | VIELDS 100% 0 <sub>2</sub> .  RISKS DEPRESSURIZATION.  MAY INTERFERE WITH OTHER TASKS.  GAS ANALYZER NOT CRITICAL FCR MEASURING PARTIAL 0 <sub>2</sub> . | % O <sub>2</sub> ).  RISKS FARTIAL DEPRES- SURIZATION.  MAY INTERFERE WITH OTHER TASKS.  GAS ANALYZER REQUIRED TO READ PARTIAL PRESSURE O <sub>2</sub> . | (85% 0 <sub>2</sub> ).  NO DEPRESSURIZATION RISK. LITTLE INTERFERENCE WITH OTHER TASKS.  GAS ANALYZER REQUIRED TO READ PARTIAL PRESSURE 0 <sub>2</sub> . |
|--------------------|--|--|--|
| WEIGHT (           | LEAST.<br>8.2 LES (10  | 12 LBS (85% O <sub>2</sub> ).  | 16 LES (85   |
| TIME TO COMPLETE   | FASTEST.  30 TO 45 MINUTES USING AVAILABLE GOX (5.6 LBS), 70 MINUTES USING CRYO ONLY.  | 90 MINUTES TO YIELD 85% 02 USING SOME GOX (2.2 LBS). 105 MINUTES USING ONLY CRYO.  | 115 MINUTES TO YIELD 85% O2 USING SOME GOX (2.2 LBS). 130 MINUTES USING ONLY CRYO.   |
| ИЕТНОБ             | DEPRESS TO ZERO  | DEPRESS TO 2 FSIA  | NO DEPRESS   |

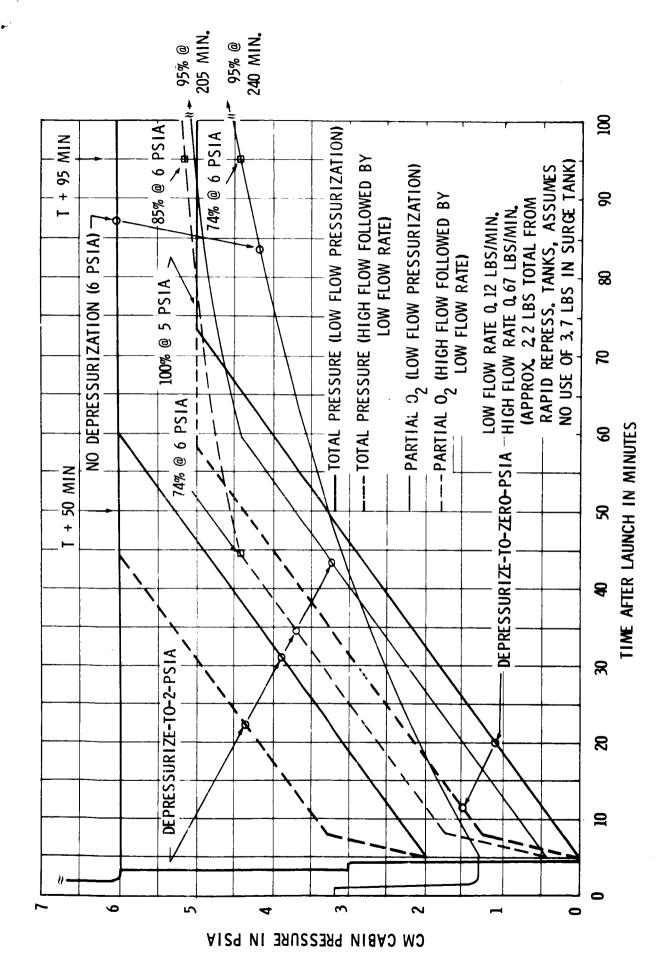


FIGURE 1 - AIR TO OXYGEN EXCHANGE PARAMETERS FOR CM CABIN

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Method of Changing the CM

Atmosphere from Air to Oxygen DATE: September 30, 1967

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